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UNITED STATES
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DEPARTMENT CIRCULAR 388

Washington, D. C. July, 1926

RESISTANCE IN SUGAR BEETS TO CURLY-TOP

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U. S. Department of Agriculture

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INTRODUCTION

The curly-top disease of sugar beets has long been a limiting factor in the development of the beet-sugar industry in many parts of the Western States. In several regions into which the industry has ventured it has been abandoned on account of this disease, and in other districts its existence is in a precarious condition for the same reason. Vast areas otherwise suitable for beet growing remain practically undeveloped because of the curly-top menace. It is evident, therefore, that from the standpoint of the prosperity and development of the West and the expansion of domestic sugar production a satisfactory control of the curly-top disease is very greatly needed. No practicable method for controlling the leaf hopper which spreads the disease has been discovered, nor has any other hopeful way of controlling the disease appeared except by the development of a variety of resistant beets. That hope lay in this direction was suggested by the fact, noted by other workers and the writer, that in beet fields severely affected with curly-top many

[1] Until the season of 1925 the project was conducted in cooperation with C. F. Stahl, formerly of the Office of Truck-Crop Insects, Bureau of Entomology, United States Department of Agriculture.

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individual plants occur which have been conspicuously less injured by the disease than most of the other plants.

On the basis of this observation, a few seemingly resistant beets were selected in 1918 in the hope that eventually a strain of beets satisfactorily resistant to curly-top might be developed. In the subsequent years many more selections from commercial fields and from the progenies of such selections have been made. As seed has become available from these selections it has been planted in a locality (Riverside, Calif.) where the beet leaf hopper occurs, and in addition the plants have been uniformly inoculated by caging viruliferous leaf hoppers on each one. Check rows of commercial beets were similarly treated. In addition to the tests of the strains selected for resistance to curly-top, tests have been made in two different years of a considerable number of strains of sugar beets which have been developed for desirable characters other than resistance to curly-top. These latter strains have been developed at Fort Collins, Colo., by W. W. Tracy, jr., of the Office of Sugar Plants.

The two main difficulties which have retarded progress have been the lack of satisfactory methods of keeping the beet roots over winter in a mild climate and of preventing undesired hybridizations between selected individuals and between these and Swiss chard and other types of beets. The latter difficulty has been especially troublesome, because isolation by means of paper bags or cloth cages has not been found satisfactory, and the prevention of cross-pollination has been attempted through isolation by distance. Even though progress has been slow, the results each year have encouraged the hope that the desired end may in time be reached. In view of the fact that the work of the past season (1925) has given the most striking results, it seems advisable to call attention to some of them rather than to review all the work thus far done.

TESTS WITH STRAINS SELECTED FOR RESISTANCE TO CURLY-TOP AND FOR OTHER CHARACTERS

The tests made in the season of 1925 included 24 strains which had been developed by Tracy without reference to curly-top and a larger number of strains selected by the writer for resistance to the disease. In view of the fact that in each of Tracy's strains the plants were fairly uniform in morphological characters, any constant differences between strains in resistance or susceptibility would be evidence that these are inherent characteristics. These strains were grown under similar conditions in parallel plots 2 by 50 feet, and in the effort to expose them uniformly to curly-top all were similarly inoculated by caging four viruliferous leaf hoppers on

each individual plant for 24 hours. The procedure and the results with Tracy's strains are given in Table 1.

TABLE 1.—*Comparative susceptibility to curly-top of 24 strains of sugar beets which had been selected for characters other than resistance in 1925*

Date inoculated and strain No.	Number of plants			Yield (pounds)	Date inoculated and strain No.	Number of plants			Yield (pounds)
	In plot	Diseased on June 10	Surviving at harvest, Sept. 25			In plot	Diseased on June 10	Surviving at harvest, Sept. 25	
May 8:					May 11:				
2158	39	39	31	19.50	2987	48	43	37	32.75
2689	42	41	27	12.75	4459	48	46	37	31.75
2921	46	46	11	5.00	4619	44	41	38	23.75
4396	47	47	23	5.50	May 13:				
5433	49	44	41	31.75	705–730	49	45	41	37.00
6598	51	48	39	31.25	2339	41	36	28	30.00
6623	46	46	25	8.75	May 14:				
7294	44	31	40	38.75	1733–1746	46	41	37	29.00
7585	44	41	31	22.00	1818	49	48	35	14.00
8854	53	50	38	23.75	1886	47	42	41	34.25
1367	54	53	13	3.75	2823–2844	47	43	42	38.50
1509	39	39	8	2.75	1962	49	47	44	39.25
May 11:									
2749	44	44	37	30.50	2445	49	49	35	35.75

As indicated by the tabulated results, there were striking differences in the extent of injury with the various strains. In some strains nearly all the plants were killed (fig. 1), while in others nearly all survived. Strain No. 7294 is worth noting further, because it was evidently somewhat resistant to infection as well as to injury.

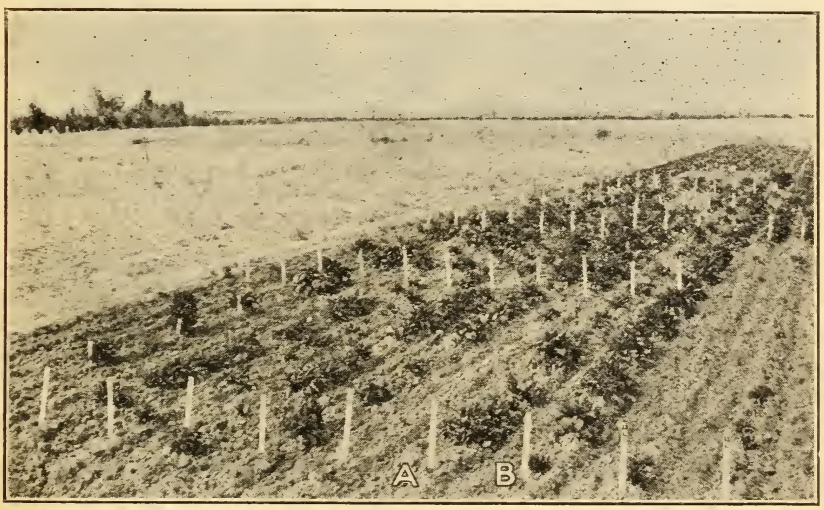

FIG. 1.—Resistance of sugar beets to curly-top. All plants were similarly inoculated. Note the contrast between the ordinary commercial beets (*A*) and the second-generation progeny from plants selected for resistance (*B*). Note also that in the two rows at the right, strains developed without regard to resistance, practically every plant died from the disease

Nineteen days after inoculation only 48 per cent of the individuals in this strain showed curly-top symptoms, while in several other strains 100 per cent of the plants were affected. In this strain the individual plants were strikingly uniform in morphological characters and fairly uniform in resistance. In other strains there was evident resistance to injury but very little resistance to infection. The rather low yield in even the strains showing resistance (fig. 2) was probably due in part to loss of vigor from inbreeding. The three nearest check plots of commercial beets yielded 16.25, 20.75, and 26.50 pounds, respectively.

The results with the strains which were selected for resistance to curly-top show definitely that some of these strains are more re-

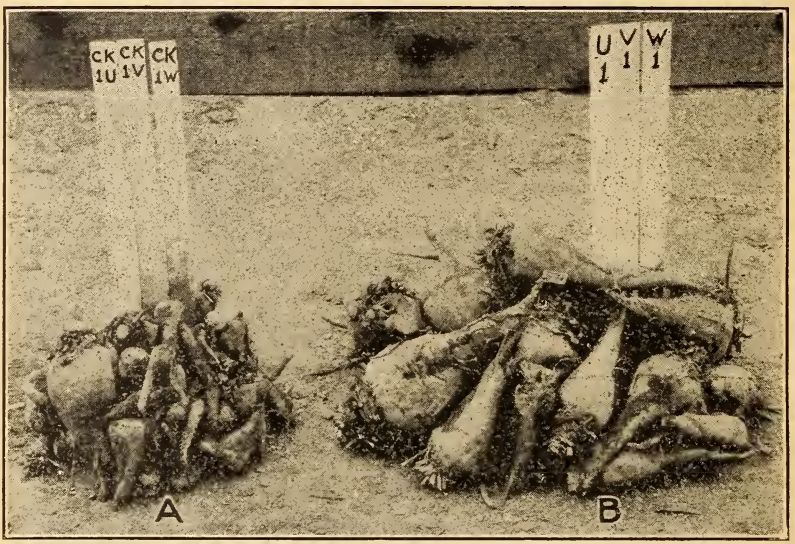

FIG. 2.—Contrasting yields of commercial and selected beets when exposed to curly-top. *A*, Roots from three sections of the check row (*A*) shown in Figure 1; *B*, roots from the adjacent three sections of the row of resistant beets (fig. 1, *B*)

sistant than the commercial strain with which they were compared. In the case of one strain (No. 286a1b7c1), the fourth generation from a selection from a commercial field, the degree of resistance was marked (figs. 3 and 4). The results with three of the more promising resistant strains and those with the controls of the commercial strain are given in Table 2. The strains were all grown under similar conditions, and all plants were uniformly inoculated.

The results detailed in Table 2 show that when grown under similar conditions and similarly exposed to curly-top 100 plants (five plots) of strain No. 286a1b7c1 yielded approximately 4½ times as much as 116 plants (five plots) of the commercial control. There

were only four replications of strain No. 2002. In this strain 69 plants in four plots gave a yield more than twice that from five control plots. Strain No. 463a3b1 also yielded more than twice as much as the controls. A noteworthy contrast between a selected strain and the control, which is not mentioned in the table, is illustrated in Figures 1 and 2.

FIG. 3.—A conspicuously resistant strain of sugar beets. The rows 1N, 2N, and 3N were of the same strain, the fourth generation from a selection. A check row of commercial beets is shown at the extreme right (CK 3E). The blank rows, 8E and 9E, were planted with seed (other strains) which did not germinate

TABLE 2.—*Results in 1925 with sugar-beet strains selected for resistance to curly-top compared with controls of a commercial strain*

[All plants were uniformly inoculated and similarly treated in other respects. Each plot was 2 by 25 feet in size]

Strain	Number of plants			Plot yield (pounds)	Strain	Number of plants			Plot yield (pounds)
	In plot	Diseased on June 10	Surviving at harvest			In plot	Diseased on June 10	Surviving at harvest	
No. 286a1b7c1	26	13	25	58.5	No. 2002	25	24	22	37.25
Do	21	5	21	41.6	Do	11	8	10	25.0
Do	17	6	17	41.6	Do	23	17	19	41.25
Do	16	5	15	29.2	Do	10	9	9	9.0
Do	20	4	20	50.0	Total	69	58	60	112.50
Total	100	33	98	220.9					
					No. 463a3b1	19	16	19	30.50
Check	22	21	16	11.25	Do	15	9	15	23.00
Do	24	21	17	15.0					
Do	23	23	9	4.0	Total	34	25	34	53.50
Do	24	24	15	7.75					
Do	23	23	16	10.75	Check	21	20	15	7.25
					Do	26	24	24	14.50
Total	116	112	73	48.75					
					Total	47	44	39	21.75

Aside from the results given in Table 2 there are other facts in regard to the most resistant strain (No. 286a1b7c1) which are significant. Three weeks after inoculation only 26 out of 100 plants were diseased, and most of these 26 were mildly affected. Practically all of the plants in the check rows were severely affected within the same time.

Resistance has been the principal character sought for, but in order to develop an entirely satisfactory beet, other characters must be considered. Unfortunately, the most resistant strain is very unsatisfactory from the standpoint of sugar content. Hybridization of this strain with strains less resistant but otherwise more desirable has been started.

FIG. 4.—Contrasting yields from commercial beets and a selected strain. From 116 plants in 125 feet of check row a yield of 48.75 pounds was harvested (*A*). From 100 plants in 125 feet of row of the resistant strain (fig. 3) 220.9 pounds were harvested (*B*)

MASS-SELECTION TESTS

In addition to the evidence already given, encouraging results were obtained in a relatively extensive test with the first-generation progeny from a mass selection for resistance. In this case a large number of beets showing the least injury had been selected from severely affected fields in the Yakima Valley of Washington by officials of the Utah-Idaho Sugar Co. These mother beets were planted together in one field at Toppenish, Wash. A generous sample of the seed obtained was sent to Riverside, Calif., for testing. Because of poor germination, there were only 349 plants of the mass-selection lot in 525 feet of row. These 349 plants yielded roots weighing a total of 434.5 pounds, whereas 492 commercial check plants in 525 feet of row yielded but 255.5 pounds. This was an increase of 70 per cent over the yield from ordinary commercial beets, even though the individual plants in the mass-selection lot varied greatly in resistance and susceptibility.

CONCLUSION

The evidence reported establishes the fact that there are definite variations among individual sugar beets in regard to susceptibility and resistance to curly-top and justifies the hope that a variety of beets satisfactorily resistant to the curly-top disease may be developed.

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